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LIFE CYCLE MANAGEMENT

ISO 14062 in theory and practice—ecodesign procedure. Part 1: structure and theory

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Abstract
Purpose The goal of the paper is to present the ecodesign procedure developed based on the guidelines of ISO 14062 standard. The article has been divided into two parts. Part 1 presents the description of the procedure's structure and its most important elements. Part 2 (Kurczewski and Lewandowska 2010) focuses on the practical aspects and presents an example of the suggested methodology application in relation to a fridge freezer.
Methods The example presented uses the environmental life cycle assessment, life cycle costing, and environmental benchmarking; however, the use of other techniques, e.g., matrix methods, social life cycle assessment, or checklists, is also possible. An innovation is the development of assessment criteria concerning the interested parties and their requirements and the use of multidimensional comparative analysis in the assessment of the design variants.
Results and discussion The result of ecodesign application is the selection of the design that meets the assumed requirements to the highest extent. They are formulated not only on the basis of environmental or economic aspects but also in virtue of the interested parties' requirements, including functionality, ergonomics, safety, etc. Ecodesign requires relatively quick and clear responses.
Conclusions The suggested procedure comprises all the key elements of ecodesign, and the result represents a compromise solution between various, often contradictory, requirements identified at different life cycle stages. The suggested procedure has been checked on a few practical examples, although it still requires verification in relation to products/services of various groups and representing various specific features (electrical and electronic equipment, packages, clothes, furniture, services, etc.).

Keywords Ecodesign · Interested parties · ISO 14062 · Life cycle assessment (LCA) · Life cycle costing (LCC) · Multidimensional comparative analysis (MCA) · Requirements

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1 Introduction

The guidelines of the ISO 14062 standard (ISO/TR 14062 2002; Quella 2003; Quella and Schmidt 2003a, b) were the starting point of this procedure. Thus, the suggested methodology (Kurczewski and Lewandowska 2008) does not represent a separate proposal; it should rather be perceived as the development of the recommendations included in the said document and other publications in the scope of DfE (Fuad-Luke 2004; Rebitzer and Schmidt 2003; Wimmer and Zust 2002; Wimmer et al. 2004). Three principal platforms of ecodesign have been assumed:

- Analysis of particular life cycle stages and correlations taking place between them
- The cost and benefit analysis in relation to environmental, social, and economic aspects
- The assessment of interested parties and their requirements

According to the definition (ISO/TR 14062 2002), we may assume that the task of the design procedure is to transform the requirements into particular properties/product specification. Therefore, it should not only enable such transformation itself but also clearly indicate the types and sources of requirements as well as the methods of collecting information about them. In DfE, the requirements should be identified throughout the whole life cycle of the product designed. They really can be of various nature: environmental, economic, social, technical, esthetic, etc. Within the procedure presented, two main types of requirements have been assumed (Fig. 1), resulting from:

- Technical and physical properties of the product
- Recommendations and needs of the interested parties

2 Materials and methods

In the approach presented, the general structure of the procedure suggested by the standard has been maintained, consisting of the following stages (ISO/TR 14062 2002):

1. Planning
2. Conceptual design
3. Detailed design
4. Tests/prototype
5. Production/launching on the market
6. Product revision

Due to the extensiveness of the material, this paper will present the most important elements of the procedure only, ones that constitute a certain novelty in relation to the standard guidelines (stages 1 and 2).

2.1 Planning as the first stage of the procedure

The input information of the first stage of the procedure should be the set of information on the object representing the input technological level as well as the set of requirements (acknowledged as the most important ones) formulated by the key interested parties (originating both from the internal and external environment of the firm). In other words, stage 1 shows the difference between what really exists and what should be there, according to the requirements of the interested parties and recommendations formulated in virtue of the reference object analysis (Fig. 2).

The *Planning* stage includes five steps presented in Fig. 3. The starting point is (step 1.1) the appointment within the organization of an interdisciplinary team including people from the key departments of the firm. It is important that the team appointed should have knowledge of the firm's strategy and sufficient decision-making power in order to perform the particular stages within the ecodesign procedure as well as the knowledge of the questions related to the products at all the stages of its life cycle. The second step (step 1.2) within the planning stage is the formulation of the target, which is done by the ecodesign team appointed. The formulation of the target is the key element influencing the test scope, type of reference object, and the quantity and type of parties interested.

Further, the selection of the reference object is made (step 1.3.1). The reference object is a starting point representing a certain basic technological level (technical, structural, functional, qualitative, ergonomic, cost, social, environmental, etc.) that the ecodesign is started with. There are two potential situations determined by the target of the tests:

- Design of an entirely new product: the lack of the "predecessor" brings about the search for the reference object outside, e.g., a product representing the best available technology; the product selected would approximately correspond to the object selected
- Improvement of an existing product where the "predecessor" with well-known and precisely determined parameters does exist

The reference object must be well recognized and characterized (step 1.3.2). In the first place, one should make its characteristics through the definition of the following elements: technological level the product represents, the structural aspects (type of elements, type of materials, weight), and the usability aspects (durability, functionality, ergonomics, power consumption, potential misbehaviors of the users).

In step 1.3.3, the environmental aspects generated throughout the whole life cycle of the analyzed input

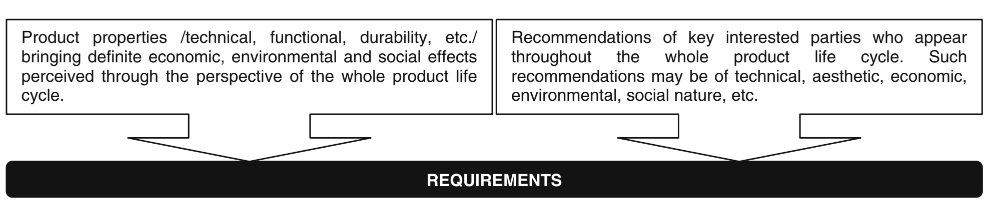

Fig. 1 Sources of requirements in the ecodesign procedure

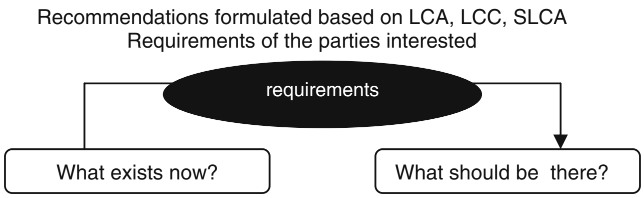

Fig. 2 Requirements as the basis for target condition formulation in ecodesign

object are assessed. The LCA and matrix techniques can be used for this purpose (Graedel 1996; Hochschorner and Finnveden 2003; Hur et al. 2005). Whatever method has been applied, the result of this step should be the obtainment of the following information (preferably in the quantitative form):

- What the overall environmental effect generated throughout the life cycle by the reference object is
- What the environmental effect generated by the particular stages is and which of them contributes to the environment degradation to the highest extent (production, transport, usage, disposal),
- What environmental issues are potentially caused by the reference object throughout its life cycle (climate changes, ozone layer deterioration, fossil fuel depletion process, eutrophication)
- What elements (processes, materials, structural elements, emissions, etc.) are mainly responsible for creating the negative environmental effect

Summarizing, this step should give explicit information on what the main reason for the environmental effect is and what areas of design should be changed. Identical analyses can be made in relation to the economic and social aspects, obtaining information concerning the main sources and places of creating economic–environmental–social costs. The ecodesign recommendations are formulated based on these costs, and they are to be defined clearly and transparently so as to translate the procedures into tasks at later stages and assessment criteria in a multicriteria analysis. They should refer to measurable parameters that can be expressed quantitatively in a specific unit.

Another stage (1.4) in the scope of *planning* is the definition of the target condition. The result of the preceding step (1.3) is the information on the weaknesses of the input object, such weaknesses should be modified and designed. The definition of the target condition consists in the identification of the requirements of all the relevant interested parties who are understood as entities related directly or indirectly to the product (throughout its life cycle) and as entities related to or “afflicted” by the ecodesign results. From this design stage point of view, the most important thing is the fact that the interested parties are treated as *product-correlated requirement* (*preference*) *carriers* and should meet at least one of the following criteria:

- Influence the sales amount and generation of profit on sales of the product analyzed/designed
- Be related (actually or potentially) to the accomplishment of any product life cycle stages (from conceptual phases to final disposal)
- Influence the formation of the environmental effect of the product designed
- Feel the benefits or negative effects of design either directly or indirectly

In step 1.4.1, the identification of the parties interested is made without assessing them. Considering the fact that the interested parties appearing throughout the whole life cycle are analyzed, collecting information on their requirements and considering such requirements in ecodesign could excessively complicate the whole procedure. Therefore, step 1.4.2 has been introduced, consisting in the significance assessment (in 0–5 scale) of the parties interested. The proposed assessment criteria are presented in Table 1.

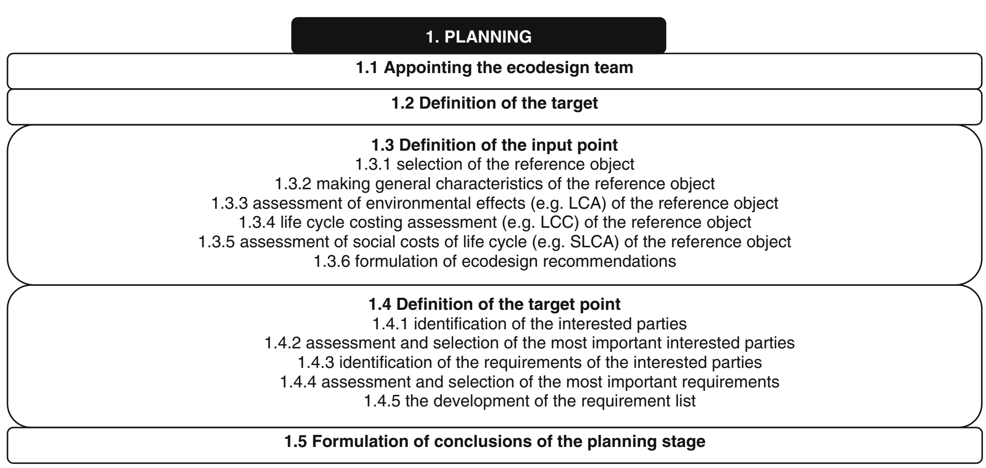

Fig. 3 The structure of the planning stage

Table 1 Parties interested assessment criteria in ecodesign

Priority	Correlation coefficient	Characteristics	Share in ecodesign
Critical	5	Direct and very strong effect on sales amount and profit formation Necessary for accomplishment of at least one of the life cycle stages Capable of making decisions having significant environmental effects Directly and strongly influence the design process or "benefit" from its effects Compulsory from the company's point of view	Very active—it is absolutely necessary to identify the interested parties requirements acknowledged as critical and consider them in the design
High	4	Direct and significant effect on sales amount and profit formation Significant for the accomplishment of at least one of the life cycle stages Capable of making decisions that may bring about environmental effects Moderately, directly or indirectly influence the design process or "benefit" from its effects Optional from the company's point of view, but important due to the strategy assumed	Active—it is necessary to identify the requirements of the high-priority interested parties and to consider them in the design
Medium	3	Moderate direct or indirect influence on sales amount and profit formation They may appear during the performance of at least one life cycle stages They have a limited influence on the generation of environmental effects Indirectly influence the design process or "benefit" from its effects	Moderately active—it is desirable to identify the requirements of the medium-priority interested parties and include it the design
Weak	2	Weak indirect influence on sales amount and profit formation May appear during the performance of at least one of the life cycle stages They have a restricted influence on the generation of environmental effects No effect on the design process, but they directly "benefit" from its effects	Passive—optional identification of this kind of interested parties' requirements
Very weak	1	Scarce or no influence on sales amount and profit formation They may appear during the performance of at least one of life cycle stages Scarce or no influence on generation of environmental effects Indirectly related to the ecodesign process effects	Passive—it is possible to exclude this kind of parties from the ecodesign process
Insignificant	0	No influence on sales amount and profit formation May appear during the performance of at least one of the life cycle stages No influence on the generation of environmental effects No correlation with the ecodesign process effects	Passive—it is possible to exclude this kind of parties from the ecodesign process

It is beneficial to assess and classify the interested parties at the input, prior to their formulation of requirements because it allows eliminating those interested parties who, despite their presence in the life cycle, play no key role from the assumed ecodesign intention point of view and it allows restricting the efforts, time, and costs.

In the further step of the ecodesign procedure (1.4.3), information on the interested parties' requirements is

collected; however, it only concerns the parties acknowledged key ones (priorities 3–5). The formulation of the requirements by the parties interested is a difficult task, the more so that they may comprise three platforms: environmental, social, and economic. The experience shows that one cannot explicitly divide the interested parties' requirements into the said three areas. They are not completely severable. For example: the potential buyers may formulate a wish to reduce the refrigerator's power consumption. Such a requirement is of an economic (operating cost reduction) and social (user's money saving) nature but also environmental (lower environmental impact related to electricity production).

The group appointed for the ecodesign purposes should thoroughly plan the communication procedures with the interested parties and those of obtaining feedback from them. In such a case, we should assume the most pessimistic variant and assume that the stakeholders do not know the ecodesign concept and in consequence may be unaware of their role and participation in the life cycle of the product designed and may have problems with the formulation of the requirements (the lack of knowledge, time, willingness). The solution of such problems seems to be the arrangement of a series of meetings with the representatives of all the key interested parties (priorities 5–3) and informing them on the ecodesign principles and target assumed. Different forms of obtaining information will be used in relation to the stakeholders originating from the company's internal environment and different in relation to the complex external environment. To improve the communication with the parties interested, the ecodesign team should consider the option to develop a list of suggested specific requirements for a given product that will be assessed (and arranging in hierarchy) by the interested parties. In practice, it is brought down to sending questionnaires to the stakeholders with an open list of requirements and blank space to enter the significance coefficients.

A specific example of a party interested includes the competitors. The list of questions directed to them and concerning the requirements is not an appropriate tool to be used. The EB—*environmental benchmarking*—is suggested instead (Wimmer and Zust 2002; Wimmer et al. 2004). The requirements formulated by the key stakeholders will later become the basis for determining the criteria in the analysis of the multicriteria selection of a design solution.

From the preceding steps (1.4.1, 1.4.2, and 1.4.3), we obtain information on which of the identified interested parties are to be assumed as the most important and included in the design process. The requirements are selected in an identical way. The starting point from step 1.4.3 includes all the requirements claimed by the most important stakeholders. Further, within step 1.4.4, the assessment and selection of the most important requirements are suggested out of those claimed by critical interested parties. The basis for the assessment is the attribution of coefficients in 0–10 scale (0, the least significant ones; 10, the most important ones) to particular requirements. Such assessment is made by the stakeholders themselves. The ecodesign team should receive filled out forms (Table 2) with attributed significance coefficients (the forms to be filled in are sent to parties interested recognized as key ones only).

Only the requirements with the highest significance coefficient should proceed to the further steps of the procedure, i.e., those that were recognized important or the most important by all the key stakeholders. An arbitrary question is which value of the significance coefficient should be the top limit for exclusion of the requirements.

Table 2 Assessment of significance of requirements claimed by parties interested

Requirement	Interested party 1 Significance coefficient of party interested (3–5) x_1	Interested party 2 Significance coefficient of party interested (3–5) x_2	Interested party 3 Significance coefficient of party interested (3–5) x_3	…n … x_n	Total significance coefficient
Requirement A	Significance coefficient (0–10) for requirement A attributed by party 1 A_1	Significance coefficient (0–10) for requirement A attributed by party 2 A_2	Significance coefficient (0–10) for requirement A attributed by party 3 A_3	… A_n	$\sum_{i=1}^{n} x_i \times A_i$
Requirement B	Significance coefficient (0–10) for requirement B attributed by party 1 B_1	Significance coefficient (0–10) for requirement B attributed by party 2 B_2	Significance coefficient (0–10) for requirement B attributed by party 3 B_3	… B_n	$\sum_{i=1}^{n} x_i \times B_i$
Requirement C	…	….	…	…	
Requirement Z	Z_1	Z_2	Z_3	Z_n	$\sum_{i=1}^{n} x_i \times Z_i$

The list of requirements is created based on the results obtained (step 1.4.5) that proceed to the further stages of the ecodesign procedure.

2.2 The conceptual design as the second stage of the procedure

Another stage of the procedure comprises the creation of the conceptual design. Its scope includes the steps presented in Fig. 4. The ecodesign tasks at the stage of creating the conceptual design are formulated in the first place. The basis for their creation are two information streams obtained from steps 1.3 and 1.4 (as in Fig. 3).

3 Discussion

The ecodesign tasks should be specific, expressed in a definite unit and showing the target level that should be achieved in the design process. For example, a recommendation obtained from the LCA, LCC, and SLCA tests (step 1.3) can be *the reduction of noise level emitted by the device while being used*. At the same time, *the noise reduction* also is one of the most important requirements indicated by the key interested parties. If the reference object indicates noise level equal to 60 dB, the corresponding competitors' product is characterized by the level of 55 dB (environmental benchmarking result); the ecolabeling criteria impose the level of 53 dB, and the users would like to have a device working with a lower noise emission (without showing any specific value); the target level is the value of 53 dB. In such a situation, the ecodesign task will be formulated as follows: noise level reduction to 53 dB (*reduction by 11.6% compared to the reference object*). The performance of the ecodesign task will allow fulfilling the ecolabel requirements, achieving the advantage over the competitive product, and obtaining users satisfaction. The task of the ecodesign team is to define the ways of achieving the target included in the ecodesign task. This is related to the suggestion of structural changes in the way of fulfilling the function so far (reference object) that in consequence led to the reduction of noise emitted by the device during its usage. Thus, the so-called variants (step. 2.2) are formulated, constituting the ideas of the ecodesign team concerning the noise reduction (task accomplishment): the application of vibration damping elements during the operation of the refrigerating unit, replacement of the traditional electrical units with magnetic ones, or reduction of the number of refrigerating units (Fig. 5) (Kurczewski and Lewandowska 2010).

3.1 Ecodesign variant assessment with the use of the multicriteria comparative analysis

At this stage of the procedure, information on the methods of performing the particular ecodesign tasks (variants) is obtained. A desirable situation is the fulfillment of several criteria by a given variant. If the reduction of the number of refrigerating units not only leads to noise reduction but also to the reduction of energy consumption, such solution brings a double benefit (Kurczewski and Lewandowska 2010). The principal question faced by the ecodesign team at this stage of the procedure is the issue of *which of the suggested variants are the best.* There are a few aspects that additionally complicate the decision making.

- Different variants may differently fulfill the ecodesign task (e.g., the application of damping elements will reduce the noise level to 55 dB, replacement of the units to 53 dB, and reduction of the number of the units to 51 dB)
- A particular variant may fulfill more than one ecodesign task (e.g., the reduction of the number of units not only leads to the reduction of noise but also to the reduction of energy consumption)
- The ecodesign tasks may be of various significance level (e.g., noise reduction is less important than the reduction of energy consumption or increasing the product durability)

To select the optimum variants (fulfilling the assumed ecodesign tasks in the best way), it is suggested to apply within step 2.3 of the procedure a multicriteria analysis (MCA), according to the example presented in part 2 of the

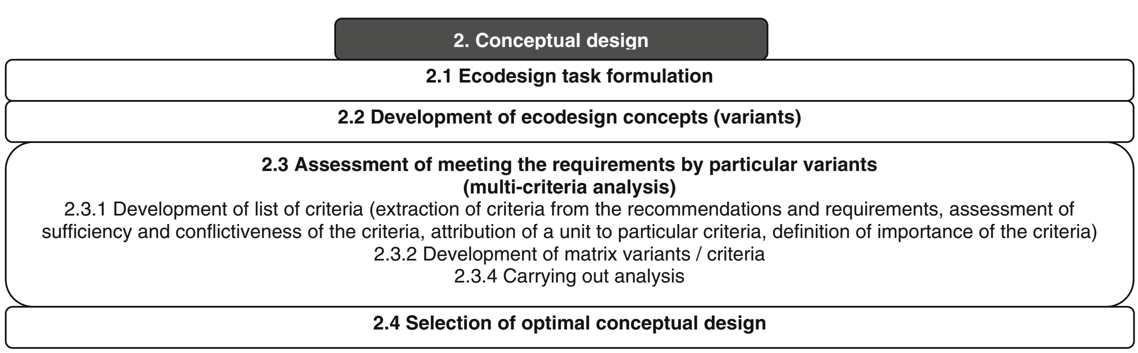

Fig. 4 Structure of the *conceptual design* stage

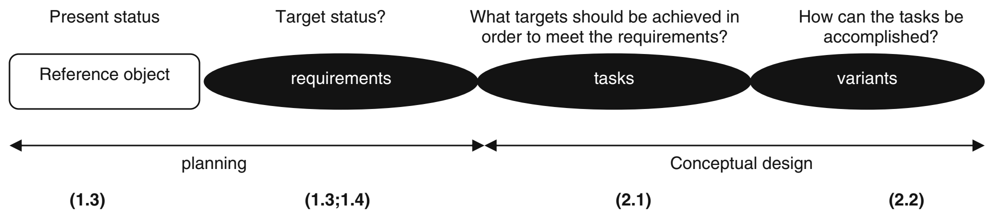

Fig. 5 Relations between *planning and conceptual design*

paper. The following are the arguments for using MCA to select the best ecodesign variant(s):

- It enables us to compare many different and even conflicting criteria formulated by various interested parties.
- MCA includes "the best variant" represented by a target level for each criterion.
- The criteria used and the results obtained are quantitative, which makes the interpretation of the MCA results transparent and easy.
- Multicriteriality of MCA means not only including many criteria but also selecting the best ecodesign variant(s) according to the principle where *the more criteria met*, *the better is the variant.*
- A methodology of MCA is well established and widely used in practice in many areas of life, e.g., in economy, building industry, and sociology.

The result of the multicriteria analysis is the arrangement of variants according to their performance extent of a particular criteria. The best variant will be the one that shows the shortest distance towards the target values of the criteria and the lowest value of the so-called synthetic development measure. It is suggested to select the best conceptual methods (variants) for the further design stage and subject them to detailed assessment.

4 Results

The result of stage 2 is the selection of the best conceptual methods (variants). On the one hand, we know that these are the best solutions meeting the given criteria; however, the information held thereon at this stage of the procedure are too general and demand more details. Therefore, the variants selected by means of the MCA go to the *detailed design* stage. The detailing and specification are made here in terms of, e.g., material selection, production technology, or making structural documentation. The data collected at this stage should possibly include the whole life cycle. Further, the detailed designs move on to a further stage of the procedure, i.e., *tests*, and are subjected to another assessment in terms of the environment (LCA), economic (LCC), and social aspects (SLCA) (Fig. 6). The result of this stage should be the explicit selection of a specific detailed design that will be manufactured and launched on the market.

5 Discussion and conclusions

Ecodesign requires relatively quick and transparent responses. However, taking into consideration its extensive scope and multilevel and multicriteria nature, it is difficult to grasp all the key elements in a simple approach. In the ISO 14062 standard, it is clearly emphasized that the ecodesign result should be a compromise between various, often contradictory requirements and needs. The suggested method leads to the obtainment of consistent, clear, and understandable results. However, it is not among the simple tools and requires knowledge and experience of the researcher. It seems, however, that no significant ecodesign areas have been omitted or simplified. The suggested procedure was checked on several practical examples, although it still needs to be verified in relation to the products/services of various groups and showing different specific characteristics. The life cycles themselves, interested parties, and their demands and influence structure shall be formed differently, depending on the group the

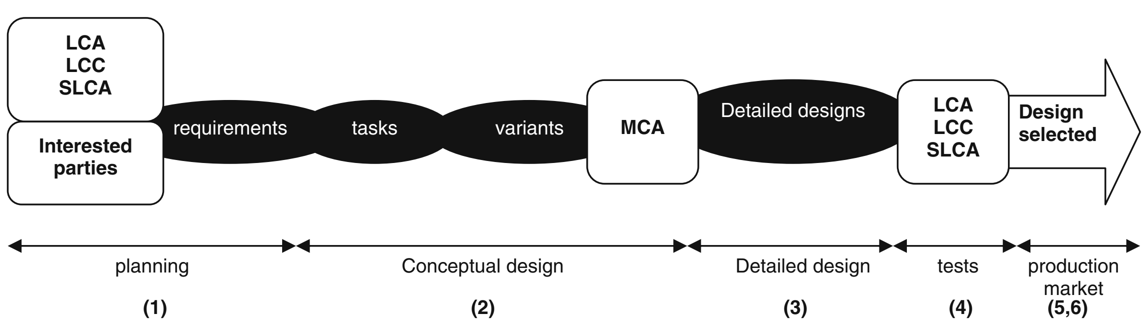

Fig. 6 Information flow in the ecodesign procedure

designed object belongs to, whether it is an electrical or electronic equipment (Lewis et al. 2001), furniture, clothes, packages, or automotive industry products (Rebitzer and Schmidt 2003).

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